NAME:_____

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UNIVERSITY OF SASKATCHEWAN
DEPARTMENT OF CHEMISTRY
CHEMISTRY 111.3
FINAL EXAMINATION

December 10, 1998

Time: 3 hours

SIGNATURE:_____

STUDENT NO.:_____

Please indicate your Section:

☐	01 Baranski	MWF	8:30
☐	03 Verrall	MWF	11:30
☐	05 Quail	TTH	10:00
☐	07 Reid	MWF	10:30
☐	09 Waltz	MWF	9:30
☐	11 Mezey	MWF	14:30
☐	13 Silerova	MWF	9:30

☐	C11	Zimpel (Melfort)	
☐	C15	Zee (Prince Albert)	
☐	C61	Walker (Yorkton)	
☐	C97	Iqbal (Muenster)	

INSTRUCTIONS:

1. This examination consists of 12 pages including a data sheet. Please ensure your paper is complete.

2. Answer all questions on the examination paper. For multiple choice questions, circle the correct answer on the examination paper and enter the answer on the blue optical scan sheet by filling in the appropriate circle with a dark pencil.

3. Complete the information required (name etc.) at the top of the optical scan sheet. Your Student Number is to be coded onto the upper left portion of the sheet reading downward. Note that the numbers in the code spots read from zero through nine as you read from left to right ... i.e. the first spot is 0, not 1.

4. Show your work in problem solutions. Ensure that your answer has the appropriate units and number of significant figures.

5. This is a closed book examination. The marks for each question are indicated. Total marks are 160. Allowing for reading the questions and checking over, this is 1 mark per minute; apportion your time accordingly.

Additional Information:

$K_w = 1.0\times10^{-14}$ at 25°C

Roots of quadratic equation $(a \cdot x^2 + b \cdot x + c = 0)$:

$$x_1 = \frac{-b - \sqrt{b^2 - 4ac}}{2a}, x_2 = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

Question	Maximum Marks	Marks Awarded
1-30	90	
31	12	
32	8	
33	16	
34	7	
35	5	
36	5	
37	7	
38	10	
Total	**160**	

Section A: Multiple Choice Questions (3 marks each).

1. A single $^{35}Cl^-$ ion has:

A. 17 electrons
B. 20 neutrons
C. both A and B
D. neither A nor B

2. The distinguishing characteristic of all electrolyte solutions is that they

A. contain molecules.
B. conduct electricity.
C. react with other solutions.
D. always contain acids.
E. none of them.

3. Identify the major ions present in an aqueous solution of HNO_3.

A. HN^+, O^{2-}
B. OH^-, NO_3^-
C. OH^-, NO
D. H^+, N^{3-}, O^{2-}
E. H^+, NO_3^-

4. The oxidation number of N in $NaNO_3$ is

A. +6
B. +5
C. +3
D. −3
E. none of them

5. What volume of concentrated nitric acid (15.0 mol L^{-1}) is required to make 1.00×10^2 mL of a 3.00 mol L^{-1} nitric acid solution?

A. 1.00×10^2 mL
B. 2.00×10^1 mL
C. 5.00×10^2 mL
D. 15.0 mL
E. 3.00 mL

6. Consider two colours of visible light. One (X) has a wavelength twice the other (Y). Thus:

A. X has twice the frequency and twice the energy per photon of Y
B. X has twice the frequency and half the energy per photon of Y
C. X has half the frequency and twice the energy per photon of Y
D. X has half the frequency and half the energy per photon of Y

7. The first ionization energy of atoms generally:

A. increases down the Periodic Table, and from left to right
B. increases up the Periodic Table, and from left to right
C. increases down the Periodic Table, and from right to left.
D. increases up the Periodic Table, and from right to left

8. Consider the following sets of quantum numbers for an electron in an atom. Which are valid?

	Quantum numbers			
Set	n	ℓ	m_ℓ	m_s
X	3	2	1	+1/2
Y	2	2	1	-1/2
Z	3	2	2	0

A. X & Y
B. X & Z
C. Y & Z
D. X only
E. Y only

9. Which of the following substances has a standard enthalpy of formation at 25 °C equal to zero?

A. $CO_2(s)$
B. $H_2O(liq)$
C. $N_2(g)$
D. $N_2(liq)$
E. $C_6H_6(g)$

10. An exothermic reaction causes the surroundings to

A. warm up.
B. become acidic.
C. condense.
D. decrease in temperature.
E. release CO_2

11. Calculate the density in g/L of CO_2 gas at 27°C and 0.50 atm pressure.

A. 0.89 g/L
B. 1.12 g/L
C. 9.9 g/L
D. 46 g/L
E. 2.2 kg/L

12. Two identical containers at the same temperature are filled with O_2 and H_2, respectively, to give identical pressures. Which of the following statements is false?

A. The number of molecules of H_2 and O_2 is the same.
B. The number of moles of H_2 and O_2 is the same.
C. The average kinetic energy of the H_2, molecules and the O_2 molecules is the same.
D. The average speed of the H_2 molecules and the O_2 molecules is the same.
E. The O_2 container (with contents) weighs more than the H_2 container (with contents).

13. One reason that real gases deviate from ideality is the

A. rapid motion of the molecules
B. non-zero volumes of each molecule
C. catalytic effect of the container walls
D. presence of impurities
E. frequent elastic collisions between molecule

14. Helium atoms do not combine to form He_2 molecules, yet He atoms do attract one another weakly through

A. dipole-dipole forces.
B. ion-dipole forces.
C. dispersion forces.
D. ion-ion forces.
E. hydrogen bonding.

15. Which one of the following substances should exhibit hydrogen bonding in the liquid state?

A. PH_3
B. H_2
C. H_2S
D. CH_4
E. NH_3

16. Which of the following indicates the presence of relatively weak intermolecular forces in a liquid?

A. a relatively low heat of vaporization
B. a relatively high critical temperature
C. a relatively low vapor pressure
D. a relatively high boiling point
E. none of the above.

17. According to the collision theory, all collisions do not lead to reaction. Which choice gives both reasons why all collisions between reactant molecules do not lead to reaction?

i) The total energy of two colliding molecules is less than some minimum amount of energy.
ii) Molecules cannot react with each other unless a catalyst is present.
iii) Molecules that are improperly oriented during collision will not react.
iv) Solids cannot react with gases.

A. i & ii
B. i & iii
C. i & iv
D. ii & iii
E. iii & iv

18. Which of the following statements is true, given the overall reaction

$$2NO_2 + F_2 \rightarrow 2NO_2F$$

which proceeds through the following two step mechanism

$$NO_2 + F_2 \rightarrow NO_2F + F$$
$$NO_2 + F \rightarrow NO_2F$$

and obeys the rate law $\text{rate} = k_{observed}[NO_2][F_2]$

A. The reaction is third order overall.
B. The order of the reaction cannot be determined from the information given.
C. The second step is rate determining.
D. F is an intermediate.
E. None of the above statements is true.

19. For the reaction $H_2(g) + I_2(g) = 2HI(g)$ $K_c = 50.2$ at 445°C

if $[H_2] = [I_2] = [HI] = 1.75 \times 10^{-3}$ mol L^{-1} at 445°C, which one of the following statements is true?

A. The system is at equilibrium, no change.
B. The concentrations of HI and I_2 will increase as the system approaches equilibrium.
C. The concentration of HI will rise as the system approaches equilibrium.
D. The concentrations of H_2 and HI will fall as the system moves toward equilibrium.
E. The concentrations of H_2 and I_2 will increase as the system approaches equilibrium.

20. Which is the correct equilibrium constant expression for the following reaction?

$Fe_2O_3(s) + 3H_2(g) = 2Fe(s) + 3H_2O(g)$

A. $K_c = \dfrac{[Fe_2O_3][H_2]^3}{[Fe]^2[H_2O]^3}$ B. $K_c = \dfrac{[H_2]}{[H_2O]}$ C. $K_c = \dfrac{[H_2O]^3}{[H_2]^3}$

D. $K_c = \dfrac{[Fe]^2[H_2O]^3}{[Fe_2O_3][H_2]^3}$ E. $K_c = \dfrac{[Fe_2O_3][H_2]}{[Fe][H_2O]}$

21. The equilibrium constant for the reaction $Ni(s) + 4CO(g) = Ni(CO)_4(g)$ is 5.0×10^1 at 25 °C. What is the value of the equilibrium constant for the reaction?

$Ni(CO)_4(g) = Ni(s) + 4CO(g)$

A. 2.0×10^{-5}
B. 2.5×10^{0}
C. 5.0×10^{1}
D. 5.0×10^{-4}
E. 2.0×10^{-3}

22. The following reaction occurs by a single (elementary) step in both the forward and the reverse directions:

Reaction: $2\,A = B$ K_c = equilibrium constant

The rate constant for the forward step ($2\,A \rightarrow B$) is k_f and that for the reverse process ($B \rightarrow 2\,A$) is k_r. Which of the following equations gives the relationship between K_c and the rate constants?

A. $K_c = k_f/k_r$

B. $K_c = k_r/k_f$

C. $K_c = k_f k_r$

D. $K_c = (k_f)^2/k_f$

E. None of the above

23. Which one of the following compounds is most likely to be a covalent molecule?

A. KF
B. $CaCl_2$
C. SF_4
D. Al_2O_3
E. $CaSO_4$

24. Consider Lewis structures of the following covalent molecules. Which one requires <u>more than one</u> resonance structures?

A. CO_2
B. $ClNO_2$
C. H_2O
D. CH_4
E. H_2S

25. Which one of the following molecules is nonpolar?

A. NH_3
B. OF_2
C. CH_3Cl
D. H_2O
E. $BeCl_2$

26. Which of the following salts has the <u>highest</u> molar solubility?

A. SrF_2	$K_{sp} = 2.8 \times 10^{-9}$
B. $Zn(OH)_2$	$K_{sp} = 1.8 \times 10^{-14}$
C. PbI_2	$K_{sp} = 1.4 \times 10^{-8}$
D. BaF_2	$K_{sp} = 1.7 \times 10^{-6}$
E. PbS	$K_{sp} = 3.0 \times 10^{-28}$

27. A buffer solution contains <u>equal</u> <u>concentrations</u> of a weak acid and its sodium salt. Its pH is 4.20. Which acid is being used?

A. Formic acid, $K_a = 1.74 \times 10^{-4}$
B. Benzoic acid, $K_a = 6.3 \times 10^{-5}$
C. Acetic acid, $K_a = 1.75 \times 10^{-5}$
D. none of A), B) or C)

28. What is the pH of a 0.0048 mol L^{-1} solution of KOH?

A. 11.68
B. 8.43
C. 4.82
D. 3.70
E. 2.32

29. Hydrofluoric acid, HF, is a weak acid for which $K_a = 3.5 \times 10^{-4}$. The value of K_b for the F^- ion is:

A. 2.9×10^{-11}
B. 3.5×10^{-4}
C. $2.9 \times 10^{+3}$
D. 2.9×10^{-9}
E. 3.5×10^{-5}

30. All of the following are conjugate acid base pairs EXCEPT

A. HCO_3^- and CO_3^{2-}
B. RNH_3^+ and RNH_2
C. H_3O^+ and OH^-
D. CH_3COOH and CH_3COO^-
E. HCN and CN^-

Section B. Other Questions (Marks in brackets)

31. (12 marks)

When 1.201 g of an organic compound conteining C, H, and O was burned completely in oxygen, 1.760 g of CO_2 and 0.7206 g of H_2O were produced.
(a) How many mole of CO_2 were produced?

(b) How many moles of H were present in 1.201 g of the organic compound?

(c) How many grams of O were present in 1.201 g of the organic compound?

(d) What is the empirical formula of the compound?

32. (8 marks)
Fill in the blanks in the following table. A sample row has been filled in for you. You may use orbital 'box' diagrams instead if you wish.

Name of element	Number of protons	Ground-state Electronic Configuration
sulfur	16	[Ne] $3s^2\ 3p_x^2\ 3p_y^1\ 3p_z^1$
calcium		
	9	
	12	
gallium		

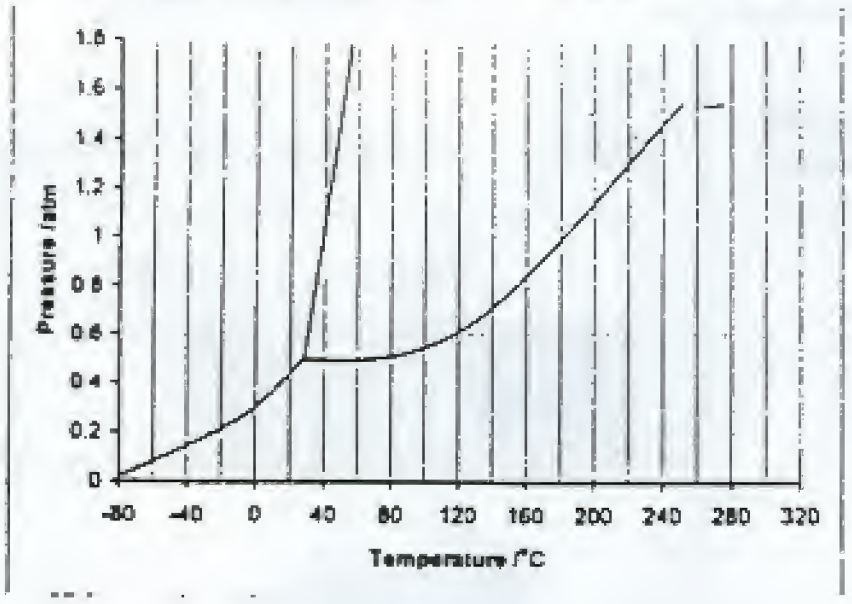
33. (16 marks)
Fill in the following table

Molecule or Ion	Number of Valence Electrons	Lewis Structure	Description of Molecular Shape*	Hybridization of the central atom
H<u>C</u>N				
<u>N</u>O_3^-				
<u>C</u>H_2F_2				
<u>B</u>Cl_3				

*Describe the arrangement of atoms around the central atom. Central atoms are underlined.

(32)

34 (7 marks)
(a) Based on the following phase diagram determine the normal (1 atm) freezing point, the normal boiling point and identify the phases present at
P = 1.5 atm, t = -20 °C and P = 0.8 atm, t = 200 °C.



The normal freezing point is _____ °C

The normal boiling point is _____ °C

At P = 1.5 atm and t = –20 °C the substance exists as _____

At P = 0.8 atm and t = 200 °C the substance exists as _____

(b) Arrange OF_2, F_2 and HF in order of increasing boiling point:

.....<.....<.....
lowest bp. highest bp.

35. (5 Marks)
Consider the following process which is initially at equilibrium:

$$PCl_5(g) = PCl_3(g) + Cl_2(g) \qquad \Delta H^0 = 92.5 \text{ kJ}$$

In which direction *(left to right, right to left or no change)* will this reaction proceed to reestablish equilibrium after each of the listed actions?

Action:	Response:
a) Temperature is raised,	.....
b) Cl_2 is added,	.....
c) PCl_3 is removed,	.....
d) Unreactive He is added without change in volume of the container,	.....
e) A catalyst is added,	.....

36. (5 marks)
Given the following thermochemical equations, calculate the standard enthalpy of formation for propane, $C_3H_8(g)$.

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H^\circ = -393\ kJmol^{-1}$
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H^\circ = -286\ kJmol^{-1}$
$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(l)$ $\quad \Delta H^\circ = -2219\ kJmol^{-1}$

37. (7 marks)
(a) The pH of a 0.060 mol L^{-1} aqueous solution of a monoprotic acid is 3.44. Calculate K_a of the acid.

(b) Calculate K_b of the conjugate base.

38. **(10 marks)**

In a study of the reaction of pyridine (C_5H_5N) with methyl iodide (CH_3I) in a benzene solution at 25 °C, the following initial rates were measured at different initial concentrations of C_5H_5N and CH_3I:

$[C_5H_5N]$ (mol L^{-1})	$[CH_3I]$ (mol L^{-1})	Initial rate (mol L^{-1} s^{-1})
1.00×10^{-4}	2.00×10^{-4}	1.5×10^{-6}
2.00×10^{-4}	2.00×10^{-4}	3.0×10^{-6}
2.00×10^{-4}	3.00×10^{-4}	4.5×10^{-6}

(a) Give the rate law for this reaction.

(b) Calculate the rate constant at this temperature.

(c) Predict the initial reaction rate at 25 °C when the initial concentrations of C_5H_5N and CH_3I are 5.00×10^{-5} mol L^{-1} and 2.00×10^{-5} mol L^{-1}, respectively.

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